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POPULATION DYNAMICS: FINAL REPORT

20 December 1968

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Work Unit 2312D

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TECHNICAL MEMORANDUM

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POPULATION DYNAMICS: FINAL REPORT

Zivia S. Wurtele
(Consultant)

in collaboration with

Jean B. Wellisch

20 December 1968

SYSTEM DEVELOPMENT CORPORATION
2500 COLORADO AVE.
SANTA MONICA
CALIFORNIA
90406

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For

Office of Civil Defense
Office of the Secretary of the Army
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SRI 12488 (6300A-480)
Work Unit 2312D

ABSTRACT

This document describes the results of an investigation of the feasibility of developing a method for determining the spatio-temporal distribution of the population. A model is described which can be used to determine the location of the population in Standard Location Areas on an hourly basis. Costs for acquisition of the data inputs to the model and processing of the model are estimated, and a method for validating the model is suggested.

ACKNOWLEDGMENT

We would like to thank Valdimir Almendinger, Ken Hinman and Michael Kevany of Urban Systems Research, System Development Corporation, for their assistance in this study. Almendinger and Hinman provided information on the computer method and costs in using Origin and Destination survey data. Kevany conducted a survey for use of data sources in the Los Angeles region. We are grateful to Robert McCornack, head of Statistical Services at SDC, for the statistical computations. We would also like to acknowledge our debt to Karl Wellisch of the State of California Division of Highways who did much to acquaint us with the extensive Transportation Studies literature.

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SUMMARY

OBJECTIVE

A study was conducted, the purpose of which was to investigate the feasibility of developing a method to determine the spatio-temporal distribution of the population. Feasibility, in this case, was interpreted to mean that the method developed should have two characteristics: one, skilled personnel using computer technology should be able to implement the method; and two, costs involved in implementing the method should be within reasonable limits.

A model for determining the distribution of the population in Standard Location Areas on an hourly basis was developed which appears to meet the required conditions.

DATA SOURCES

The imposed cost limitation required that input data for the model should be readily available and entail a minimum of costly special surveys. Consequently, Transportation Studies including area Origin and Destination trip surveys which are available on a nationwide scale, and Federal, state, county and city census data were the data inputs on which the model was developed.

DESCRIPTION OF THE MODEL

A mathematical model was formulated for estimating spatio-temporal distributions of populations for relatively small areal and temporal units. The areal units are Standard Location Areas (S.L.A.), and the temporal units are hours. The model was formulated in terms of: (1) a characterization of land use-activities (residential, commercial, industrial, educational, recreational, etc.); and (2) a characterization of the diurnal variations in people's participation in these activities. Land use-activities are determined for each small areal unit (S.L.A.) for which population is to be estimated. The model requires information on numbers of employees, number of residents and number of students, within S.L.A.'s. In contrast, the diurnal variations are related to the region or even to the nation as a whole, and are not estimated separately for small areal units. Accordingly, the inputs to the model are differentiated into two groups--variables and parameters. The variables, which are specific to the S.L.A.'s, describe the distribution of activities within the S.L.A.'s. The parameters are associated with diurnal variations and not dependent upon S.L.A.

INPUTS OF THE MODEL: VARIABLES

R_α = the number of non-institutional residents of S.L.A.α.

I_α = the number of institutional residents of S.L.A.α.

$E_{i\alpha}$ = the number of employees of industry i located in S.L.A.α, for $i = 1, \ldots, p$.

S_α = the number of elementary and high school students enrolled in S.L.A.α.

v_α = the number of special institutions considered separately in S.L.A.α.

$Z_{i\alpha}(t)$ = the number of persons present in special institution i at time t in S.L.A.α, for $i = 1, \ldots, v_\alpha$ and $t = 1, \ldots, 24$.

The subscript α refers to the α^{th} S.L.A. All of the variable inputs are specific to S.L.A., but only the variables $Z_{i\alpha}(t)$ depend upon t. The variables $Z_{i\alpha}(t)$ may be introduced if the general methods developed here are not appropriate for predicting attendance at certain institutions in an S.L.A., such as a university, a bathing facility, a stadium. If such an institution accounts for a significant proportion of the S.L.A.'s population, it is classified as special, and data are collected on numbers of persons present by hours of the day, by means of special surveys. If in S.L.A.α no such special institutions are considered, then $v_\alpha = 0$.

INPUTS OF THE MODEL: PARAMETERS

$r(t)$ = the proportion of residents at home at time t, for $t = 1, \ldots, 24$.

$e_i(t)$ = the ratio at time t of persons present (employees and others) to the total number of employees of industry i, for $i = 1, \ldots, n$ and $t = 1, \ldots, 24$.

$s(t)$ = the ratio of persons present (students, teachers, and other staff members) to the total number of elementary school and high school students enrolled, for $t = 1, \ldots, 24$.

$m_i(t)$ = the proportion of persons that are en route at time t on trips that are associated with land use i, for $t = 1, \ldots, 24$.

The parameters do not depend upon S.L.A. Whereas a variable measures the total amount of land use-activity within the S.L.A., the corresponding parameters describe how this activity is distributed over the hours of the day. To the extent that a temporal distribution of this type is institutional and relates to national characteristics, parameters that are estimated for one region may be employed in another. Similarly, if these characteristics are relatively slow to change with time, data for parameter estimates need not be too current.

The parameters $e_i(t)$ and $r(t)$ can be estimated from Origin and Destination Traffic Studies, for which relevant data are collected on all trips taken during 24-hour periods by members of the sample households of Study Areas. Data required for estimation of these parameters are generally included in these Traffic Studies.

OUTPUTS OF THE MODEL

$M_j(t)$ = the number of persons en route in S.L.A. j at time t, for $t = 1, \ldots, 24$.

$P_j(t)$ = the number of persons present in S.L.A. j at time t, for $t = 1, \ldots, 24$.

EC ION OF THE MODEL

$$P_\alpha(t) = r(t)\, R_\alpha + \sum_{i=1}^{p} e_i(t)\, E_{i\alpha} + s(t)\, S_\alpha + I_\alpha + \sum_{i=1}^{v_\alpha} Z_{i\alpha}(t) + M_\alpha(t) \cdot$$

Each term of this sum is an estimate of the number of persons present by hour and land use-activity. The total number present is obtained by summing up over all the categories.

Several models of this general type were formulated. These differ from each other with respect to their specifications of inputs. The variable inputs of these models depend to a large extent on: (1) data which are collected regularly throughout the nation by the Bur u of the Census and by the Bureau of Labor Statistics; and (2) on data which are routinely collected by School Boards. The parameters may be estimated (1) from regional Origin and Destination Traffic Studies which are executed under the supervision of the Bureau of Public Roads; and (2) from information from School Boards. The models can thus be implemented in a uniform way throughout the country and with relatively little additional data collection. More refined models which require additional investment in data collection are also discussed; whether outputs of such models are sufficiently improved in accuracy to warrant the additional costs of implementation cannot be ascertained in advance.

COSTS

The availability and costs for collection of the variable input data to the model were investigated for one city - Los Angeles. Data processing techniques and costs for parameter estimation were investigated for several representative Traffic Studies throughout the country.

CONCLUSION AND RECOMMENDATION FOR MODEL VALIDATION

It is a conclusion of the report that this model is a potentially useful tool for predicting population distribution by hour of the day and by S.L.A. In formulating the model, an effort was made, on the one hand, to restrict input requirements to generally available data, so that the model could be implemented in towns and cities throughout the nation with a minimum of supplementary data collection. And on the other hand, the model was designed so as to utilize all regularly collected relevant statistics, as well as results of related special surveys which may have been made in individual regions. The goal was to develop a model that is sufficiently flexible to include as inputs, wherever possible, supplementary local data on population distribution, as well as routinely collected population and employment statistics of the U.S. Census Bureau and the Bureau of Labor Statistics, school attendance records of school boards, and information derived from Origin and Destination traffic studies.

The next stage in this process of model development is to implement the model and to compare model outputs with those obtained in some other fashion. A relatively cheap method for accomplishing this task is recommended; this method utilizes Origin and Destination traffic study data for making the necessary comparisons.

INTRODUCTION

Knowledge of the location and movements of people within a city is of extreme importance to a number of agencies involved in civic administration, planning, commercial and industrial activities, and civil defense. Traffic engineers need data on the movement of people and traffic flow to determine the optimum location of streets and highways. City planners require such data to plan for future development in terms of the land-use distribution needed to accommodate a burgeoning population. The retail merchant needs to know the shopping travel patterns of the population he expects to draw on. Industrial interests which, while less interested in the proximity of markets, are very interested in the residential location and accessibility of a pool of employees. In general, administering and improving the city, and planning for future growth--public transportation, utilities, schools, recreational areas--presupposes knowledge of not only where people live, but of where they engage--and prefer to engage--in all the activities that comprise their lives.

For the purposes of many of the agencies discussed above, population locations and movement patterns in terms of gross trends, diurnal and seasonal variation, for large areas of the city are sufficient. For the purposes of civil defense, however, much finer detail--hourly fluctuations in small areal segments--is required.

In civil defense the need for dynamic population data is for purposes of warning, sheltering, evacuation and casualty estimation.

- For warning, the interest is in determining an optimum complement of warning methods and warning systems. For this purpose, data in terms of the population of people who are situated so as to hear public siren systems, radio alerting and warning messages, and institutional warning systems is desired.

- For Community Shelter Planning (CSP) there is a need to know how people are distributed in relation to available fallout shelter, recognizing that such distribution may change greatly at different hours of the day and days of the week.

- For evacuation and casualty estimation the population distribution data has to be in even finer grain than that required for warning and shelter. Where planning for warning systems and shelter has been proceeding with available gross population data, for either natural or man-made disasters, data on small area population distribution must precede any substantive planning for evacuation and casualty estimation.

Various contractors to the Office of Civil Defense have attempted to locate the population in time and space concomitant with work in these areas--warning, shelter and casualty estimation. For instance: in the CSP for New Orleans, The Regional Planning Commission (1968) attempted to estimate resident, peak daytime, and nighttime population distributions; in a study of nuclear damage to New Orleans, Dikewood Corporation (1968) estimated the distribution of the total population and the distribution of key personnel; and, for a survey of outdoor warning, SDC (1968) tried to estimate the proportion of people outdoors at various times of the day.

None of the methods used in these studies for determining population distribution have been entirely satisfactory, mainly because estimates were for gross time intervals and geographic areas. Consequently, OCD has asked SDC to investigate the feasibility of developing a method that would provide population distribution data for Standard Location Areas in short time intervals. The scope of the study as defined in the contract is as follows:

"SCOPE OF WORK: The work to be performed will include:

(1) A survey and collection of data available on the distribution of population versus time, and a survey of techniques and methods available for extrapolating and predicting spatio-temporal population distribution.

(2) The development of appropriate categories for organizing the data collected.

(3) Fitting the data collected in (1) above, to the categories developed in (2) above.

(4) Development of methods that can be used to adapt spatio-temporal population data, and predictive techniques, to various classes of cities and parts of the country.

(5) Development of models of the spatio-temporal population distribution for one or more types of cities, and [determination of] data gaps and [analysis of] their overall significance for warning and shelter.

The feasibility study is intended to include a determination of

1. What data are required
2. The location or sources of the data
3. The relative availability of the data and its credibility
4. The means for acquiring the data
5. The cost of acquisition

The study should also assess the sensitivity of population movement and location determinations to partial acquisition, degradation, or the complete absence of specific data and the degree of confidence in study results that can be expected from the acquisition of varying amounts and quality of input data to include an estimate of the percentage of the population whose location can probably be predicted.

It should be noted that the study is not directed to any particular city or community. Rather, the general parameters involved in consideration of date-time and geographical regions should be assessed and a coarse grained initial population movement and location of assessment technique should be developed. The technique would provide for modifications that regional and other ecological factors may be expected to impose so that with proper consideration of the variables, the technique could be applied to any representative community."

In this document the results of this investigation are described. In the following chapter the relevancy of available data is discussed; in Chapters II and III models for determining the spatio-temporal distribution of the population are described; Chapter IV estimates the costs involved in data acquisition and running the model; and in the final chapter a method is recommended for testing and refining the model.

CHAPTER ONE

RELEVANT DATA

In analyzing the feasibility of developing a method to determine the spatio-temporal distribution of the population, the approach taken was that a method would be feasible if it met two conditions: (1) the method should be sufficiently simple and straightforward that skilled personnel using available computer technology could use it; and (2) the costs of data acquisition and running of the model should be within the limits of a foreseeable Office of Civil Defense budget.

The model itself is described in the next chapters; here, the kinds of data to be used with the model are discussed. To a large extent the kind of data that were available determined the nature of the model. This study was not viewed as an academic exercise requiring an elegant solution; instead, a very practical method in terms of technology and cost was sought. Consequently, very early in the study, concentration was on a methodology that could utilize mainly data that were fairly standardized, representative of all parts of the United States, and available. Available, that is, in the sense of being already collected by some agencies and not requiring costly, special surveys.

Much of the data finally decided upon, on which to build the population distribution model, have the required characteristics. These data are: Federal, state, county and city census data; and, Origin and Destination survey data collected by city transportation departments. For a long time Federal census data has been the most standardized and dependable data collected on a national scale. State, county and city census type data, particularly employment, business and school data, are becoming more universally collected and more standardized, and the trend is for continuance in this direction. Today, almost all of the metropolitan areas of the country are surveyed in the Origin and Destination studies and very sizeable samples of the population are used.

Census information is in a sense static. Data are provided on the resident, institution, employee and student populations. Origin and Destination data, on the other hand, are dynamic. Information is provided on the movement of people--when they go to work, where they leave from, where they go, and when they leave. From the one--census type data--the variables of the model are derived; from the other--O & D data--the parameters are derived. The manner in which both kinds of data are used in the model and costs of acquisition are described in the following chapters.

Although these are the data used, other data and methodologies were of interest and influenced the development of the model. In general, however, other methods were found to be too costly in their requirements for data acquisition. The work done for the Federal Civil Defense Administration by the Bureau of the Census in 1956,[1] for instance, required special surveys to determine the relation of total employment to workers and others present in retail and industrial establishments. And this, at what today would be great cost, was only to help determine one peak hour population distribution in a few cities. In another example of an older population study, Weir (1960), page 655, says in his survey of the daytime population of Winnipeg, "Were it possible at a specific time during a typical working day to bring the inhabitants of a metropolitan area to a standstill, and then by means not yet devised make a simultaneous count relative to location, the result would be an accurate census for that particular time. Such is beyond all bounds of practicability. A realistic alternative is to make a canvass of all places where people dwell, work, study and play, and in addition to count transients on streets, in stores and public buildings. Even this would be a task more formidable than the decennial census." However, the method actually employed by Weir, a component survey, is also considered too costly for our purposes, although such a method might be used for validation

1. This method is discussed in Chapter II.

purposes. Weir divided the city into land use areas. Then a survey of every business and industrial establishment was made on a block-by-block basis. Counts of pedestrians and vehicles were made. Residential, nighttime population counts were based on the 1951 Federal Census and a sample of blocks was enumerated to discover the numbers at home during the day time. In this way a ratio between nighttime and daytime population was obtained and applied to the nighttime population of all the tracts. By totalling and correcting the various components of his survey, Weir was able to estimate a daytime population count.

Of course, part of the problem in the older methodologies for determining population distribution was that good, uniform and universal data, other than Federal Census data, simply were not readily available. Although several years ago the possibilities in using data collected by the transportation departments, especially data from Origin and Destination surveys and Cordon counts[1] was recognized, until very recently such data did not cover the country and was not very standardized. And also, of course, the perspective of these earlier studies was not to develop a method for determining hourly distributions throughout the country.

Another kind of study, Time-Budget studies, provides data which could be used to determine population distribution, but here too, available data is insufficient and special surveys would be prohibitive. Time-Budget studies are conducted in most industrialized countries of the world including the United States. In the United States studies of this type began in the 'thirties,[2] usually in an endeavor to determine the time spent on various activities by particular groups or classes of people. Recently, the United States has been taking part in an international Time-Budget research program under the auspices of the United Nations Institute for Training and Research (UNITAR).[3]

1. See Bureau of the Census (1957) and Institute for Research in Social Science (1952). In Chapter II these studies and their influence on the present model are described.

2. See, for example, Lundberg (1934) and Sorokin (1939).

3. See Robinson (1967), Rokkan (1966), Szalai (1966).

The Time-Budget studies might be said to be complementary to the transportation studies--Origin and Destination surveys try to identify movement patterns--Time-Budget surveys attempt to get at activity patterns. Specifically, the UNITAR Time-Budget Project has initiated a comparative study of the distribution of time spent on various activities by different populations. In the United States the work is being done at the Survey Research Center of the University of Michigan. To date, there has been a survey of one small city in Michigan and a national survey using 1500 respondents. Through conversations and correspondence with Alexander Szalai of UNITAR and Philip Converse of Michigan, we have determined that the information collected would be made available at minimal cost. However, although the data include not only what activities were engaged in but also where and when, the sample surveyed is too small to provide useful information for this project at this time. Later perhaps, the Time-Budget survey data might be used to compare gross trends and patterns of activities as these are derived from the model; or, should there be cases in the future where the same city is described by both the model method and a Time-Budget analysis, there exists the possibility of checking the one against the other.

Other literature surveyed was of interest, although at this stage it was of heuristic value only. Such studies as Alford (1965), Arnold (1964), Deutsch (1961), Goldstein (1964), and Smith (1959)[1] are so fragmental, dealing with only one aspect of population distribution--the 'journey to work,' or 'residential location and urban mobility,' for instance--that they were of little help in either providing a methodology or a source of descriptive data. Other studies--Bureau of Public Roads (1965a), Cani (1961), Fidler (1967), Fisher (1966),[2] for example--were of relatively immediate help in evaluating the available data and in model construction.

1. See Bibliography for others.

2. See Bibliography for others.

Though some of the literature surveyed was not immediately useful at the present stage of investigation, economic, social and psychological studies may be helpful in the analysis of outputs generated by the model. The distribution of the population in a city at any hour responds to the topography and the distribution of facilities within the city; and the land uses in the city are influenced by activity patterns of groups of individuals. Studies of interrelationships among these factors may assist in the interpretation of data, and in anticipating changes in the distribution of population in response to changes in the physical and social environment.

CHAPTER TWO

THE GENERAL MODEL

INTRODUCTION

In this chapter, a mathematical model is formulated for estimating spatio-temporal distributions of populations for relatively small areal and temporal units. The areal units are Standard Location Areas (S.L.A.),[1] and the temporal units are hours.

It is assumed that the presence of an individual in a given S.L.A. at a given hour is a function of (1) the activity he is engaged in, and (2) certain institutional and sociological patterns which result in his participating in the given activity at the given hour.

Each of these factors is treated explicitly in the model; inputs related to these two factors are then combined to obtain the outputs. The model is formulated in terms of (1) a characterization of land use-activities (residential, commercial, industrial, educational, recreational, etc.); and (2) a characterization of the diurnal variations in people's participation in these activities. The term "land use-activity" is introduced here, for, in this analysis, activities are differentiated according to their land uses.[2] For example, all activities within the home are residential. Similarly, eating in a restaurant is categorized as retail activity; working in or visiting a factory are associated with industrial activity; and so on. Land use-activities are determined for each small areal unit (S.L.A.) for which population is to be estimated; the

1. In tracted areas, S.L.A.'s are generally the same as Census Tracts. See Bureau of the Census (1962a).

2. It is important to distinguish between this approach and one which focuses directly on the individual's activities such as eating, dressing, etc. See, for example, Sorokin (1939), Szalai (1966), and Robinson (1967).

model requires such information on these activities as number of employees, number of residents and number of students, within S.L.A.'s. (It may be noted that to obtain outputs at a given level of detail, it is, in general, necessary to employ some inputs at the same level of detail.) In contrast, the diurnal variations are, to a large extent, related to the region or even to the nation as a whole, and are not estimated separately for small areal units. Accordingly, the inputs to the model are differentiated into two groups--variables and parameters. The variables, which are specific to the S.L.A.'s, describe the distribution of activities within the S.L.A.'s. Parameters are associated with diurnal variations and are not dependent upon S.L.A.

The feasibility of utilizing this type of model throughout the country depends, in part, upon the extent to which this dichotomy of inputs can be established without impairing results. It depends also upon the quantity and quality of the inputs that are required, and upon their availability.

The formal structure of the models is described below. Several models of this general type are introduced in the next chapter. These differ from each other with respect to their specifications of inputs. The degree of detail specified for inputs, e.g., the level of aggregation for land uses, will generally affect outputs. The variable inputs of these models depend to a large extent on (1) data which are collected regularly throughout the nation by the Bureau of the Census and by the Bureau of Labor Statistics, and (2) on data which are routinely collected by School Boards. The parameters may be estimated (1) from regional Origin and Destination Traffic Studies, which are conducted under the supervision of the Bureau of Public Roads, and (2) from information from School Boards. The models may be implemented in a uniform way throughout the country and with relatively little additional data collection. More refined models which require additional investment in data collection are also discussed; whether outputs of such models are sufficiently improved in accuracy to warrant the additional costs of implementation cannot be ascertained in advance. It is necessary to test these models by implementing them and comparing results before such questions may be answered.

THE GENERIC MODEL

INPUTS OF THE MODEL: VARIABLES

The following variables are inputs to the Model:

R_α = the number of non-institutional residents of S.L.A.α.

I_α = the number of institutional residents of S.L.A.α, as defined by the Bureau of the Census.

$E_{i\alpha}$ = the number of employees of industry i located in S.L.A.α, for $i = 1,\ldots, p$.

S_α = the number of elementary and high school students enrolled in S.L.A.α.

v_α = the number of special institutions considered separately in S.L.A.α.

$Z_{i\alpha}(t)$ = the number of persons present in special institution i at time t in S.L.A.α, for $i = 1,\ldots, v_\alpha$ and $t = 1,\ldots, 24$.

The subscript α refers to the α^{th} S.L.A. All of the variable inputs are specific to S.L.A., but only the variables $Z_{i\alpha}(t)$ depend upon t.

The variables R_α, I_α, $E_{i\alpha}$, S_α are self-explanatory; they are measures of land use-activities within the S.L.A. The variables $Z_{i\alpha}(t)$ may be introduced if the general methods developed here are not appropriate for predicting attendance at certain institutions in an S.L.A., such as a university, a bathing facility, a stadium. If such an institution accounts for a significant proportion of the S.L.A.'s population, it is classified as special, and data are collected on numbers of persons present by hours of the day, by means of special surveys. If in S.L.A.α no such special institutions are considered, then $v_\alpha = 0$.

INPUTS OF THE MODEL: PARAMETERS

The following parameters are inputs to the Model:

$r(t)$ = the proportion of residents at home at time t, for $t = 1, \ldots, 24$.

$e_i(t)$ = the ratio at time t of persons present (employees and others) to the total number of employees of industry i, for $i = 1, \ldots, p$ and $t = 1, \ldots, 24$.

$s(t)$ = the ratio at time t of persons present (students, teachers, and other staff members) to the total number of elementary school and high school students enrolled, for $t = 1, \ldots, 24$.

$m_i(t)$ = the proportion of persons that are en route at time t on trips that are associated wi h land use i, for $t = 1, \ldots, 24$. This parameter is defined in the section below, ESTIMATION OF OUTPUT $M_\alpha(t)$.

The parameters do not depend upon S.L.A. Whereas a variable measures the total amount of land use-activity within the S.L.A., the corresponding parameters describe how this activity is distributed over the hours of the day. To the extent that a temporal distribution of this type is institutional and relates to national characteristics, parameters that are estimated for one region may be employed in another. Similarly, if these characteristics are relatively slow to change with time, data for parameter estimates need not be too current.

The main source of such data are Origin and Destination Traffic Studies. During the past two decades traffic surveys have been carried out, under the supervision of the Bureau of Public Roads, in urban areas throughout the country.[1] In these surveys relevant data are collected on all trips taken during a 24-hour period by members of the sample households of the Study Area.

1. See Figure A-1 of the Appendix.

OUTPUTS OF THE MODEL

The outputs of the Model are:

$M_\alpha(t)$ = the number of persons en route in S.L.A.α at time t, for $t = 1,\ldots, 24$.

$P_\alpha(t)$ = the number of persons present in S.L.A.α at time t, for $t = 1,\ldots, 24$.

EQUATION OF THE MODEL

The number of persons present is computed from the equation:

$$P_\alpha(t) = r(t)\ R_\alpha + \sum_{i=1}^{p} e_i(t)\ E_{i\alpha} + s(t)\ S_\alpha + I_\alpha + \sum_{i=1}^{v_\alpha} Z_{i\alpha}(t) + M_\alpha(t)\ .$$

Each term of the above sum is an estimate of the number of persons present by hour and land use-activity. The total number present is obtained by summing up over all the categories. Outputs for different seasons and days of the week may be calculated by employing inputs for corresponding seasons and days of the week; the form of the model does not change. Also, if, in a particular S.L.A., data are available on persons present by hours of the day for some institutions within a land use category, the model is sufficiently flexible to utilize this information. These institutions are classified as special, and the data are recorded as $Z_{i\alpha}(t)$; in addition, the number of employees (or residents, or students) of this special institution are subtracted from the appropriate land use-activity.

ESTIMATION OF THE OUTPUT $M_\alpha(t)$

In order to run the model, it is necessary to estimate $M_\alpha(t)$, the number of persons en route at time t in S.L.A.α. The following procedure for making these estimates utilizes trip data from an Origin and Destination Traffic Study.

Let n be the number of residents included in the Traffic Study sample. Let $n\, m_i^{(1)}(t)$ be the number of trips en route at time t with origin in land use i; let $n\, m_i^{(2)}(t)$ be the number of trips en route with destination in land use i. Let $m_i(t) = (m_i^{(1)}(t) + m_i^{(2)}(t))/2$. Let $N = \sum_\alpha R_\alpha$, where the summation is over all the S.L.A.'s in the Traffic Study area. Distribute the quantity $N\, m_i(t)$ among the S.L.A's, in proportion to the model estimates of the number of persons present in land use i at time t; let the result of this distribution be $T_{i\alpha}(t)$ Then $M_\alpha(t) = \sum_i T_{i\alpha}(t)$, where the summation is over all land uses.

HISTORICAL BACKGROUND

Studies of spatio-temporal distributions have been conducted by the University of North Carolina (1952) and by the Bureau of the Census (1956). Sources of data for the former study were Traffic Studies, whereas sources for the latter were Census surveys and specially designed surveys. The impact of these studies on the formulation of the present model will be discussed briefly, for some of the results obtained in these studies are of significance to the present investigation.

In the University of North Carolina Study, four types of functional areas were defined: Commercial, Industrial, Residential, and On-Streets. Distributions of people present at each hour of an average summer weekday for each of these functional areas were obtained for the following five cities: Erie (1948), Flint (1950), Grand Rapids (1947), Minneapolis-St. Paul (1949), and Philadelphia-Camden (1947). The data used for this study were obtained from Origin and Destination Traffic Studies for these cities. Each traffic zone or subzone was assigned to a land use category. For zones of mixed land use, assignment was made to the more extensive land use category if it characterized 40 percent or more of the zone's area. Thus, the study is concerned with areas of mixed land use, rather than pure land use.

One of the questions to be answered in connection with the present model is the extent to which parameters derived from one region may be used in another region. In the North Carolina Study, comparisons were made among the cities studied of each of the following two distributions: (1) the spatial distribution of population among these functional areas at the same time and (2) the temporal distribution of population over the hours of the day for the same functional area. Considerable variation between cities was evidenced; in fact, it is a conclusion of the Study that the differences among cities were too large to lend themselves to useful generalizations about either of these distributions.

The first of these distributions--the spatial distribution of population over land use categories at a given time--may be expected to differ widely among cities for it is dependent upon the land use patterns of a city. The rationale which underlies the present model is entirely consistent with this result; for, in the present model, each land use is treated separately and results are combined in accordance with a measure of the importance of each land use-activity (e.g., employment, school enrollment) in the S.L.A.

With regard to the second distribution--the temporal distribution of population in a given land use, the Study's conclusion about the magnitude of regional differences is of interest to the model. This result may be due to the utilization of mixed rather than pure land use areas; the authors ruled out this explanation but it is not clear from the report how strong their evidence was for doing so. Another possible explanation is that the land use categories are too broad, e.g., the mix of commercial land use and activities may differ considerably among the areas. An analysis with less aggregated land use categories would be needed to test this hypothesis.

It was decided to pursue this matter further and to review the data upon which this conclusion is based; these are contained in Table A-1, Appendix A, of the University of North Carolina (1952) report. The data of this Table were converted so as to obtain for each city and each land use the ratios of the number of persons present at the hours of the day to the number of persons present at 4 P.M. The results, which are shown in Tables A-1-4 of the Appendix below, were analyzed statistically. Computer outputs are displayed in Tables A-5-8 of the Appendix. It was found that for each of the land use categories, variation between times was significantly greater than variation between cities.

This outcome provides inductive support to the conjecture that parameters derived from one region may be used for other regions without serious impairment of model outputs.

In studying the parameters of the model, we may consider separately (1) the relative numbers of persons present in a given land use at the different hours of the day, and (2) the use of the number employed in the land use as a predictor of the number of persons present at a given time. The discussion above is concerned with the first of these factors.

In the Bureau of the Census (1956) Study, attention is focused on the second of these factors. Estimates are made of ratios of the number of persons present at 2:30 P.M. (the time at which the maximum number of persons are away from home) to number of persons employed, for four cities (Houston, Milwaukee, St. Louis, and Washington) and the following land uses: (1) residential, (2) retail, (3) finance, insurance, real estate, (4) manufacturing, and (5) all others. The means and standard deviations of these estimates are listed in Table A-9 of the Appendix.

The data of Table A-9 exhibit differences between S.L.A.'s in the Central Business District and those outside of the Central Business District. In the present model it is assumed that such differences are due primarily to the use of highly aggregated land use categories; the mix of land uses within a broad land use category may differ considerably between S.L.A.'s within and outside of the Central Business District. The solution within the framework of this model is to disaggregate land use. The effectiveness of such disaggregations may be ascertained by experimentation, e.g., by implementing the model for different levels of aggregation. If such efforts prove unsuccessful, one may consider modifications of the model in which parameters are estimated separately for the two types of S.L.A.'s. In fact, it may be necessary to go further and utilize a more complex typology of S.L.A.'s, and to estimate separate sets of parameters for each type of S.L.A.; this problem is discussed in the next Chapter.

The problem of trends in parameters will require investigation. In this connection it may be noted that Breese (1964), in an analysis of trends in hourly fluctuations, found that the maximum hour of arrival in the Central Business District of Chicago changed from 7:00 - 8:00 A.M. in 1916 to 8:00 - 9:00 A.M. forty years later.

VARIANTS OF THE MODEL: ALTERNATIVE METHODS OF ESTIMATING THE NUMBER OF PERSONS AT HOME

In the present model the estimate of the number of persons at home at time t in S.L.A.α is the product of the parameter r (t) and the number of non-institutional residents, R_α.

If the populations of all the S.L.A.'s of a region are to be estimated, it may be preferable to make these estimates in such a way that the sum of the populations of the S.L.A.'s of the region is equal to known control totals. Accordingly, one may wish to restrict the outputs $P_\alpha(t)$ so that

$$\sum_\alpha P_\alpha(t) = \sum_\alpha R_\alpha + \sum_\alpha I_\alpha + D(t),$$

where D(t) is the net increase of persons into the region at time t, and the summation is taken over all S.L.A.'s in the region. In this case, the number of persons present in the region, $\sum_\alpha P_\alpha(t)$, equals the total number of residents plus the net increase. If the region for which the population estimates are made is sufficiently large and self-contained, the quantity D(t) will be negligible in comparison with the quantity $\sum_\alpha R_\alpha$, i.e., people who live in the region also work there, and vice versa.

The requirement of consistency with control totals was made by the Bureau of the Census for its estimates of peak-daytime populations. Instead of obtaining a separate measure of residents at home, as in the present model, this was obtained as a residual. Two residual methods may be employed.

1. Define $r^*(t)$ by the following equation:

$$r^*(t)\ (\sum_\alpha R_\alpha) = \sum_\alpha R_\alpha + D(t) - \sum_\alpha \left(\sum_{i=1}^{p} e_i(t)\ E_{i\alpha} + s(t)\ S_\alpha + \sum_{i=1}^{v_\alpha} Z_{i\alpha}(t) + M_\alpha(t)\right).$$

The estimate of the number of residents at home at time t in S.L.A. α is $r^*(t)\ R_\alpha$.

2. Let H(t) be the number of persons at home at time t in the entire region.

$$H(t) = \sum_\alpha R_\alpha + D(t) - \sum_\alpha \left(\sum_{i=1}^{p} e_i(t)\ E_{i\alpha} + s(t)\ S_\alpha + \sum_{i=1}^{v_\alpha} Z_{i\alpha}(t) + M_\alpha(t)\right).$$

Distribute H(t) among S.L.A.'s in proportion to the number of residents not attending school and not employed. This method may be preferable to the one above for peak-daytime hours, but is not to be recommended for other times. It was used by Bureau of the Census (1962) for estimating peak-daytime populations for the following five metropolitan areas: Grand Rapids SMSA, Omaha SMSA, Pittsburgh SMSA, San Antonio SMSA, and San Mateo County.

VALIDATION OF THE MODEL

The theoretical basis for this model has been analyzed above. The structure of the model has been scrutinized with respect to the role of land use information in predicting spatio-temporal population distributions and with respect to the dichotomy of inputs into those that relate to the land use or industry mix within S.L.A.'s and those that depend upon institutional and psychological factors which are regional or national in character. The model formulation was found to be consistent with results obtained by other investigators. In addition, computations based upon available data on regional variation of the parameters, which are described above, indicate that it may be feasible to employ for a given region parameters that have been estimated for a different region.

The proof of the pudding, however, is in the eating. To test a model it is necessary to compare model outputs with the real world. This entails (1) running the model--estimating parameters and variables and computing outputs in accordance with the relations postulated in the model; and (2) obtaining real data on population distributions for exactly the same region and time that was used for the implementation of the model. Clearly one way to obtain such data is to enumerate persons present in S.L.A.'s for the different times of the day. Enumeration in a reasonably sized sample--say 200 S.L.A.'s--would be fairly expensive as well as difficult. An alternative is a sample survey to estimate the total populations. This method is feasible and would give independent estimates which could be compared with the model outputs. If properly designed, it could provide information on the sources of error in the model's outputs, e.g., on variations of parameters between S.L.A.'s and of variables within S.L.A.'s.

There is, however, a third and much cheaper alternative for validating the model, namely, the utilization of an appropriate Origin and Destination Traffic Study to make the required comparisons. Fairly good estimates of the number of persons present in S.L.A.'s by time of day can be obtained from the results of Traffic Studies. As is indicated below, such information could be readily obtained once personal record files are established; this involves the sorting of trip files by persons. Once this has been accomplished, tabulations by area and time would yield the required estimates. Since the number of persons interviewed is quite large (e.g., in the Los Angeles Regional Transportation Study (LARTS) area members of 35,000 households were interviewed), the precision of such estimates does not present a problem. These estimates can be compared with model outputs that are obtained for the region and time covered by the Origin and Destination Traffic Study. Thus, values of the variables would have to be obtained for the same year and the same S.L.A.'s that were investigated in the Traffic Study. The parameters of the model may be estimated from this same Traffic Study or from Traffic Studies from other regions and other times. Comparisons should be made both ways. The latter type of comparisons will provide some indication of the effects of variations in parameter values between regions and between times on the outputs of the model. All of these comparisons should be made using the different forms of the model, that is, using various levels of aggregation of the model inputs.

On the basis of tests of this type, conclusions may be drawn with respect to the validity or usefulness of the model. And, furthermore, the results obtained may indicate new directions for future research on the spatio-temporal distributions of persons, as well as modifications and improvements of the model. The testing phase, it would seem, is, therefore, the next stage in this model-development process.

CHAPTER THREE

IMPLEMENTATION OF THE MODEL

MODEL 1

In Model 1, which is a special case of the general model, the level of aggregation employed is determined primarily by considerations of data availability. An effort was made to restrict the input variables to data that are collected regularly throughout the United States by existing agencies. Where the data are not tabulated by S.L.A., such tabulations may be obtained from the collecting agencies. In urban areas the data needs of this model overlap to a large extent with those of existing organizations, such as regional and city planning associations and Traffic Study agencies. As a result, tabulations of the type required for this model have been made in many urban areas. This is a considerable advantage, for in some cases necessary data already exist on tape; and, furthermore, experience in processing the data and in utilizing the tapes may be expected to result in improved techniques for data handling and in greater accuracy.

This model may be considered to provide a first approximation to the results required. To a large extent it relies on input variables that can be estimated by means of regularly conducted surveys by governmental agencies and does not require special surveys. The severity of such limitations on inputs is costly in terms of the structure of the model. Explicit accounting of factors that may be important in determining population distributions cannot be made; industries and land uses are highly aggregated. The cost savings in data acquisition may or may not be offset by these limitations on the model structure. The gain in accuracy of the model's outputs from greater disaggregation cannot be estimated in advance. It is necessary to run the model for more than one level of aggregation and to compare results.

The inputs, outputs and equation of the model are as follows.

INPUTS OF THE MODEL: VARIABLES

R_α = the number of non-institutional residents of S.L.A.α.

I_α = the number of institutional residents of S.L.A.α.

$E_{1\alpha}$ = the number of employees in retail trade located in S.L.A.α.

$E_{2\alpha}$ = the number of employees in manufacturing, mining, construction, transportation, communication and other utilities located in S.L.A.α.

$E_{3\alpha}$ = the number of employees in wholesale trade located in S.L.A.α.

$E_{4\alpha}$ = the number of employees in finance, insurance, and real estate located in S.L.A.α.

$E_{5\alpha}$ = the number of employees in all other industries located in S.L.A.α.

S_α = the number of elementary and high school students enrolled in S.L.A.α.

v_α = the number of special institutions considered separately in S.L.A.α.

$Z_{i\alpha}(t)$ = the number of persons present in special institution i at time t, for $i = 1, \ldots, v_\alpha$.

INPUTS OF THE MODEL: PARAMETERS (for $t = 1, \ldots, 24$)

$r(t)$ = the proportion of residents at home at time t.

$e_1(t)$ = the ratio at time t of persons present (employees and others) to the total number of employees in retail trade.

$e_2(t)$ = the ratio at time t of persons present (employees and others) to the total number of employees in manufacturing, mining, construction, transportation, communication, and other utilities.

$e_3(t)$ = the ratio at time t of persons present (employees and others) to the total number of employees in wholesale trade.

$e_4(t)$ = the ratio at time t of persons present (employees and others) to the total number of employees in finance, insurance, and real estate.

$e_5(t)$ = the ratio at time t of persons present (employees and others) to the total number of employees in all other industries.

$s(t)$ = the ratio at time t of persons present (students, teachers, and other staff members) to the total number of elementary school and high school students enrolled.

$m_1(t)$ = the proportion of persons that are en route at time t on trips that are associated with residential land use.

$m_2(t)$ = the proportion of persons that are en route at time t on trips that are associated with schools.

$m_3(t)$ = the proportion of persons that are en route at time t on trips that are associated with retail trade.

$m_4(t)$ = the proportion of persons that are en route at time t on trips that are associated with manufacturing, mining, construction, transportation, communication and other utilities.

$m_5(t)$ = the proportion of persons that are en route at time t on trips that are associated with wholesale trade.

$m_6(t)$ = the proportion of persons that are en route at time t on trips that are associated with finance, insurance, and real estate.

$m_i(t)$ = the proportion of persons that are en route at time t on trips that are associated with all other land uses.

The parameters $m_i(t)$ are defined on page 23, in the section <u>ESTIMATION OF THE OUTPUT $M_\alpha(t)$.</u>

OUTPUTS OF THE MODEL

$M_\alpha(t)$ = the number of persons en route in S.L.A.α at time t.

$P_\alpha(t)$ = the number of persons present ' S.L.A.α at time t.

EQUATION OF THE MODEL

$$P_\alpha(t) = r(t)\, R_\alpha + I_\alpha + \sum_{i=1}^{5} e_i(t)E_{i\alpha} + s(t)S_\alpha + \sum_{i=1}^{v} Z_{i\alpha}(t) + M_\alpha(t),$$

for t = 1, ..., 24.

<u>DATA SOURCES FOR INPUT VARIABLES</u>

The data on number of residents may be obtained from the Bureau of the Census. For urban areas it is updated by special population censuses or by local planning agencies. If further updating is required, this should be requested from an appropriate planning organization so as to best utilize the experience in demographic estimation which has been gained by local or regional planners in recent years.

The data on total number of employees can be obtained from the Bureau of Labor Statistics, in collaboration with the State Departments of Employment Security. Quarterly data on employment are collected by the latter agency in accordance with sampling procedures established by the former. Though respondents participate on a voluntary basis, estimates are considered to be quite reliable. Many years of working with these samples have enabled the Bureau of Labor Statistics to make corrections for regional idiosyncracies in reporting for non-responses, and so forth. The employment reported is that covered by Unemployment Insurance, which is about 90% of non-agricultural employment. It is suggested that tabulations of employment by S.L.A. be requested from State Departments of Employment Security. Corrections may be necessary for (1) lack of complete coverage, and for (2) address of multi-plant manufacturers. Employers may report the address of company headquarters rather than of the plant, and this would require correction unless both were in the same S.L.A. Such corrections should be made in collaboration with the State agency.

The data on school enrollment are collected by school districts. In general, these are not tabulated by S.L.A.; however, the correspondence of school addresses to S.L.A.'s may be established by fairly inexpensive clerical work. For example, it has been estimated that this task could be carried out for the schools of Los Angeles County in one man-week of work.

The data on special institutions within the S.L.A. are obtained by means of surveys. A single survey may, however, provide data for a large number of S.L.A.'s; for example, in Los Angeles the Hospital Planning Association of Southern California collects some of the necessary information for hospitals in six Counties.

ESTIMATION OF PARAMETERS: $s(t)$

Data on public elementary and high schools are generally collected at the school district level. Estimates of the parameters $s(t)$ may be based upon school hours and average daily attendance figures. This information is generally available from school districts.

ESTIMATION OF PARAMETERS: $r(t)$, $e_i(t)$

In the past two decades, Origin and Destination Traffic Studies have been conducted in numerous urban areas throughout the country. (A listing of these studies is included in the Appendix, Figure A-1.) The raw data collected in these Traffic Studies consist of two parts: diaries of trip characteristics of members of sample households and socio-economic information about the households. Data are collected on all trips made during a twenty-four hour period, by each household member over the age of five. The primary sampling unit is the household. Sample sizes vary from 1% to 7% of the population of the Study Area, with larger sampling rates used for smaller populations.

Enough information is collected in each Study Area to obtain estimates of the parameters $r(t)$ and $e_i(t)$, for the area sampled by the Traffic Study. Study Areas vary in size considerably. The Tri-State (New York metropolitan area) Study contained 17 million people and covered an area of 11,000 square miles, whereas the Pittsburgh Study (P.A.T.S.) contained one and one-half million people and covered an area of 420 square miles.[1]

In estimating the parameters it is preferable to derive both the numerators and the denominators of these ratios from the same set of households. The information required for estimating the denominators, i.e., the numbers of persons employed in the different employment categories, is generally available for the households sampled in an Origin and Destination Traffic Study. This is usually included in the data on socio-economic characteristics of the household.

Estimation of the numerators, the numbers of persons in the land use categories by hour of the day, will usually require some reorganization of the data files. Data are routinely collected by Origin and Destination Traffic Studies on the starting time and arrival time of each trip and on the land use category of of the origin and destination of each trip. With this information for all the trips of an individual during a twenty-four hour period, it is possible to

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1. See Zettel and Carll (1962).

determine, for each hour of the day, the land use class that he occupied. A certain amount of data processing will be needed to establish new files which provide this information for each person sampled. Techniques for setting up such files and estimates of costs in terms of programming are included in the following chapter. It will be seen that this procedure is feasible in terms of cost and also because it is generally applicable to the many Traffic Studies that have been conducted.

MODEL 2

This model is the same as Model 1 with the exception of its treatment of retail trade. The ratios of the number of persons present in retail trade establishments to total number engaged in retail establishments vary considerably between S.L.A.'s. Statistical evidence of this is given in Table A-9 of the Appendix; the standard deviation of the "others present" ratio for tracts that are not downtown is large relative to other standard deviations of the Table. If this variation between S.L.A.'s is due to differences in composition of the retail trade industry within S.L.A.'s, disaggregation of retail trade industry and calculation of separate parameters for each component of retail trade may be expected to reduce this variation. In Model 2 retail trade is disaggregated on the basis of a two-digit classification. Parameters are estimated separately for each retail trade category. Employment data are obtained for each S.L.A. and for each of these retail establishment classifications.

All of these additional inputs may be obtained as indicated in the discussion of the inputs of Model 1; no other sources of data are needed. The parameters may be estimated from Traffic Studies, which, in general, use two-digit classifications. Similarly, the variables may be obtained from State Department of Employment Security tabulations. Thus, though Model 2 requires more computations, its inputs are generally as available as those of Model 1.

A two-digit classification is recommended in preference to a finer three-digit one for the following reasons:

1. It has been observed in socio-economic studies that when strata become too narrow, relations may become less stable. Furthermore, stability considerations aside, studies of statistical fits to trip data have shown that there is a point at which increasing the number of classifications of trip purpose does not yield appreciably better fits.[1]

2. The tabulations required to utilize the model at this greater level of detail would be more costly and would increase considerably the number of inputs to the model.

3. The most important reason, however, is due to data limitations, if Traffic Studies are to be used to estimate parameters. A survey of Traffic Studies throughout the country indicated that two-digit classifications are generally used; in fact, a two-digit classification has been recommended by the Bureau of Public Roads. Though detailed land use information is often obtained in household interviews, the usual rule is to employ a two-digit classification when processing such data.

In a two-digit classification, the following are retail trade categories suggested by the Bureau of Public Roads:

Retail trade--building materials, hardware, and farm equipment

Retail trade--general merchandise

Retail trade--food

Retail trade--automotive, marine craft, aircraft, and accessories

Retail trade--apparel and accessories

Retail trade--furniture, home furnishings, and equipment

Retail trade--eating and drinking

Other retail trade

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1. See, f example, Ben, Bouchard, and Sweet (1965).

The extension of the model so as to include the other factors related to persons present in retail establishments would require additional data sources, both for parameter estimation and for estimates of input variables. Whether or not this may be necessary will depend upon results of testing Model 2.

MODEL 3

A quick and easy method for estimating population distributions may be available for regions that have been surveyed by Traffic Studies or Regional Planning organizations. Organizations of this type acquire data on the variable inputs of the model on a more aggregated basis. Areal units used may be aggregations of about 10 Census Tracts; examples of such areal units in Los Angeles are City Statistical Areas employed by the City Planning Department, and LARTS Major Analysis Zones, which were established by the Los Angeles Regional Transportation Study. Data on total employment for a two-digit industry classification and current estimates of number of school children enrolled are important for a broad spectrum of regional planning activities. Such information may be expected to be incorporated into a regional data bank at an early stage in the operations of a regional planning organization. Advantage may be taken of such tabulations of input variables by implementing Model 1 or Model 2 for the larger areal units for which such data are reported. Estimates for S.L.A.'s may then be made by dividing populations equally among the S.L.A.'s within the larger areal units, or by dividing the population proportionately among the S.L.A.'s in accordance with some concomitant variable which is readily available or in accordance with judgments of experts.

This type of model can also serve an additional purpose. Estimates for the aggregated areal units can be compared with sums of corresponding estimates for S.L.A.'s obtained from Model 1 or Model 2. Total populations present can be compared in this way; and, in addition, comparisons can be made of persons present by land use or industry. Discrepancies will be due either to the variables (number of residents, number of employees, number of school children) for S.L.A.'s not summing up to the corresponding variables for aggregated areal units, or to the treatment of special institutions of the S.L.A.'s ($Z_{i\alpha}(t)$). Any such discrepancies should be identified, and, where possible, reconciled.

MODIFICATIONS OF THE GENERIC MODEL WHICH REQUIRE ADDITIONAL DATA

The purpose for which a mathematical model will be utilized determines the level of detail required of its outputs, and this, in turn, determines the level of detail of its inputs and interrelationships. Fairly detailed outputs will, as a rule, require correspondingly detailed inputs. Data availability thus plays a crucial role in the implementation of mathematical models. The tasks of data acquisition and model development need not proceed independently. The directions in which a data base is expanded can be determined, in part, by the data requirements of useful models. Similarly, models investigated initially may well be limited to those with data input or calibration requirements which can be satisfied to a large extent by existing data sources. The models described so far are of this type. The question may be raised, at this point, of what types of models should be explored if data availability is no longer a significant consideration and a deterrent to the formulation of more elaborate and presumably more accurate models. It is important to note that the accuracy of such models cannot be ascertained in advance; it will be necessary to implement the models and investigate their outputs before making judgments on their usefulness. Several modifications of the model may be considered: (1) the disaggregation of variables contained in the model, (2) the employment of different sets of parameters for different regions or for different types of S.L.A.'s, and (3) the introduction of additional variables.

The purpose of disaggregation of variables is to permit the use of correspondingly specialized sets of parameters. This is useful only if parameters for the disaggregated component variables differ from each other. The following are some initial classification criteria which may prove useful.

1. Number of non-institutional residents, by socio-economic class or by income as a surrogate for class.

2. Number of employees, by first, second, and third shifts.

3. For retail trade, two sets of parameters for each employment category: one for the ratios of the number of employees present to total number of employees, and one for the ratios of others present to total number of employees.

4. For retail trade, further classification for S.L.A.'s within Central Business District and S.L.A.'s outside of Central Business District.

5. Number of school children enrolled, by public school and by parochial school.

The establishment of a typology of regions (e.g., on the basis of size and/or geographic location) or of a typology of S.L.A.'s (e.g., on the basis of distance from Central Business District or socio-economic rating) will sharpen results if differences among parameters for the categories established have a great enough impact on model outputs. The extent of such differences cannot be ascertained *a priori*; parameter values for the classifications under consideration would have to be estimated from data in Origin and Destination Traffic Studies, as described above, or by means of special surveys. Considerable exploratory work in the selection of categories and estimation of parameters would be required before these aspects of the model structure are determined.

With regard to the introduction of new variables into the model, recent investigations of retail shopping patterns are of interest. Factors that have been studied in connection with the generation of shopping trips include size of establishment, sales, number of employees, type of retail establishment, area serviced by the establishment, proximity to similar or complementary retail establishments, distance from Central Business District.[1] Of these, Model 1 includes only the total number of employees. In Model 2, account is also taken of the type of retail establishment but not of the additional factors. Since all of these factors have been found to be useful in establishing regression relations in which numbers of shopping trips or numbers of shoppers at different times of the day are dependent variables, their introduction into the model as additional variables may be expected to improve results.

1. See for example, Cleveland and Mueller (1961), Los Angeles Regional Transportation Study (1961), Wright (1963), Voorhees and Crow (1965), Fidler (1967), and Sato (1967).

CHAPTER FOUR

DATA SOURCES AND COSTS

BUREAU OF LABOR STATISTICS

The Bureau of Labor Statistics conducts a survey of employment and hours which is based on payroll records. Population counts are compiled every three months by State Employment Security Agencies according to uniform procedures specified by the Bureau of Employment Security of the U.S. Department of Labor. Monthly data are collected from a large sample of establishments throughout the country. The universe of establishments is stratified by S.I.C. (Standard Industrial Classification) and by number of employees (six size classes). A shuttle schedule is filled out each month by each respondent; information required is obtained from payroll records. Though cooperation in this survey is voluntary, the response is considered to be quite satisfactory.

The question was considered of whether it is feasible to take advantage of the existence of this sampling frame in estimating the parameters $e_i(t)$. For instance, would it be possible to add to the shuttle schedule an additional questionnaire on employees present by hour of the day. Though such information is not usually recorded by establishments, it is possible that judgments of supervisory personnel on employees present would be reasonably accurate.

This question was discussed with officials in the Bureau of Labor Statistics. Their position was that any effort to modify the existing procedure might jeopardize their survey by antagonizing or discouraging respondents. Their reaction to our suggestion was therefore negative; but this matter might be pursued further through channels available to OCD.

ORIGIN AND DESTINATION TRAFFIC STUDIES

The use of Origin and Destination Traffic Studies to estimate parameters or to test the model will necessitate a reorganization of existing Traffic Study files so as to facilitate the retrieval of the required information. In this section, a general strategy for doing this is suggested. In addition, relevant characteristics of the files of a sample of five Traffic Studies are described.

ESTABLISHMENT OF PERSON-PRESENCE FILES

Virtually all files of home interview data collected by Origin and Destination Traffic Studies have certain common characteristics. The file typically consists of two types of records: household and trip. The former contain information about the surveyed household, about the dwelling unit the household occupies, and about individual members of the household. The latter contain data on each trip taken by a household member on the "travel date." The records are those of sample points: the usual procedure is to expand the sample characteristics of those of the sampled population by applying appropriate weights to each record. Home interview files developed in the several metropolitan Origin and Destination Traffic Studies differ primarily in the physical format of the records, coding conventions, and the extent to which nonstandard household and person information (e.g., occupation and residential movement histories) has been collected and incorporated along with the standard trip data. Sometimes, for ease of processing, the person information is repeated in all trip records for a person; in other cases, the household and person/trip records are maintained in physically separate files. The procedure suggested below applies to the common logical structure of home interview files, although it is recognized that programming would have to take into account the actual differences in physical structure among the files.

The plan is to create two types of records, which are based upon the trip records in the home interview. The trip records are first ordered on the unique person identification (ID) code and, within the person ID, on a trip departure time. In this arrangement, all trips belonging to a person are arrayed chronologically in the sequence in which they occurred on the travel date. The array represents, so to speak, the complement of a "person presence" diary that would record the land use, location, and purpose of the whereabouts of a person during consecutive time periods on the travel date. For each set of trip records pertaining to a person, two sets of records are produced: 1) Type A is a person record representing the person-presence on a particular site. The site is identified by its geographic (e.g., census tract), land-use, purpose (e.g., work, home, shopping, etc.), and any other desired locational characteristics; 2) Type B is a reformatted trip record containing the essential O-D trip information--to represent the person-presence in the transportation system ("on the road"). In addition, each record type contains the start time and duration of the "trip" or "person-presence" recorded. The figure shows the schematic contents of the two types of records. Once these records are estimated, estimates of population distribution by land use and/or census tract may be obtained by appropriate cross-tabulations or summarizations.

Record Type A (for each "person presence period")

A	Person ID	Start Time	Duration	Land Use	Census Tract Code	Purpose	Other Person Characteristics

Record Type B (for each trip)

B	Person ID	Start Time	Duration	Origin LU	Origin Purpose	Destination LU	Destination Purpose	Other O-D Character.

Figure 1. Person-Presence Records

The process described above can be readily implemented through the facilities of the MIDAS Processor. The Processor, a subsystem of the 7094 SPAN system, has been used by SDC on data from the Bay Area Transportation Study for similar types of processing involving both home interview and land-use inventory data.[1]

1. See Appendix, page 75.

COSTS

Contacts were established with administrators of several traffic studies throughout the country so that estimates could be made of data accessibility and the costs involved in implementing the procedures described in the previous section. A list of people who were helpful in providing the required information is included in the Appendix. The following are results of this investigation.

Los Angeles Regional Transportation Study (LARTS) Costs

The current LARTS study covers the period January 1967 - October 1967. Days sampled include weekends, as well as weekdays. The standard Bureau of Public Roads land use code was used to designate land uses of origins and destinations of trips. Employment data is included in the household files. Data are coded to traffic zones, which are convertible to census tracts. In summary, the information recorded is adequate for the purposes of both parameter estimation and model validation. The household file contains 200,000 records (about 5 reels of tape); the trip file contains 300,000 records (8 to 10 reels of tape). The data will not be zoned and expanded until August of this year at the earliest.

Program and machine requirements are as follows:

1) Personnel design, program, and test time - 1 man week spent over a period of 4 to 6 weeks calendar time.

2) Personnel production, run supervision, and check time - 1 man week spent over a period of 4 calendar weeks.

3) Machine time - 4 hours of 7094 or 7094 emulator time for testing

   5 hours for reduction of data and selection of items desired for retention in the data base

   5 hours for parameter estimation

   6 hours for production of the tabulations broken down by census tract

No difficulty is anticipated in obtaining the data to be copied on to SDC tape reels. Although this has not been confirmed completely, it appears quite certain that the maximum cost of obtaining the data would be for machine time spent in Sacramento doing the copying. On a small computer this could amount to approximately five hours and cost between 300 and 500 dollars. There would be an additional small charge for mailing and handling.

San Diego Costs

The San Diego study covers the period May 1966 - December 1966. Questionnaire and coding procedures are almost identical with that of LARTS. The most striking difference between the two studies is in the volume of data. San Diego has about 85,000 household records (about 2 reels of tape) and about 150,000 trip records (about 3 to 4 reels of tape). Thus, the volume is about half that of LARTS. As with LARTS, it is expected that the data will be expanded and zoned by August of this year.

Program and machine requirements are as follows:

1) Personnel design, program, and test time - 1 man week spent over a period of 4 to 6 weeks of calendar time.

2) Personnel production, run supervision, and check time - 1 man week spent over a period of 4 calendar weeks.

3) Machine time - 4 hours of 7094 or 7094 emulator time for testing

3 hours for selection of items desired for retention in the data base and reduction of the data

2 hours for parameter estimation

3 hours for production of the tabulations broken down by census tract

Data accessibility is the same as for LARTS with the exception that the cost and time required to copy the data would be about half.

Bay Area Transportation Study (San Francisco) (BATSC) Costs

The Bay Area Transportation Study (San Francisco) covers the period May 1965-December 1965. The sample is distributed over all days of the week including week-ends. Sampling rate was 4 ½%. The data includes walking trips which are excluded from most other studies. The origin and destination land use code is that recommended by the Bureau of Public Roads, with some additions. The employment status of each person interviewed is included. Correspondence data is available to convert from areal zones used in the study to census tracts. The volume of data is on the order of 98,000 person records (5 reels) and 280,000 trip records (8 reels).

Program and machine requirements are as follows:

1) Personnel design, program, and test time - 1 man week spent over a period of 4 to 6 weeks calendar time.

2) Personnel production, run supervision, and check time - 1 man week spent over a period of 4 calendar weeks.

3) Machine time - 4 hours of 7094 or 7094 emulator time for testing

   4 hours for reduction of data and selection of items desired for retention in the data base

   4 hours for parameter estimation

   5 hours for production of the tabulations broken down by census tract

Data is immediately available. Costs of obtaining the data are the same as for LARTS.

Chicago Area Transportation Study (CATS) Costs

The CATS survey is older than the others and covers the period April 1956 - October 1956. Only weekdays were included. Employment is included in trip records, which contain industry and occupation. Census tract is recorded for household location but not for trip ends. Trip origin and destination are coded to CATS Analysis Zones and are convertible to census tract (1950). There are about 57,000 household records (1 reel of tape) and 247,000 trip records (2 reels of tape).

Program and machine requirements are as follows:

1) Personnel design, program, and test time - 1 man week spent over a period of 4 to 6 weeks calendar time.

2) Personnel production, run supervision, and check time - 1 man week spent over a period of 4 calendar weeks.

3) Machine time - 4 hours of 7094 or 7094 emulator time for testing

4 hours for reduction of data and selection of items desired for retention in the data base

4 hours for parameter estimation

5 hours for production of the tabulations broken down by census tract

With regard to data accessibility, the time and cost of copying data would be about one-fourth or one-third of that for LARTS.

TRI-STATE Costs

The Tri-State Transportation Commission (New York metropolitan area) home interview survey covered a twelve month period, August 1963 through July 1964. The sample was a 1% sample of households drawn from utility company files and New York City Health Department records. Weekends and holidays were excluded from the sample. The data include some walking trips--namely walk-to-work trips. Employment data are included. The land use code for origin and destination of trips is a two-digit code adopted from the SIC code, but antedating the Bureau of Public Roads code. Census tract is included in the records. Trip records exist both in linked and unlinked forms, and factored and unfactored forms. The files contain 237,000 linked trip records, blocked in ten 355-character logical records per tape block.

The program and machine requirements are about the same as for CATS. Release of the home interview files in source record form may require negotiation with the Bureau of Public Roads.

DATA AVAILABILITY IN LOS ANGELES COUNTY

A brief survey was conducted in Los Angeles County to determine the extent to which input requirements are available for the model or for modifications of the model discussed above. It was found that although some cleaning and adjustment may be necessary, an adequate base of information on employment and school attendance does exist, so that the variable input requirements of the model can be satisfied. The following is a brief account of the results obtained from the survey.

NUMBER OF EMPLOYEES

Data are available at the State Department of Employment office. Information comes in quarterly but the data are updated every two years. Data on paper forms DE 4012A include: tax year, quarter, number of employees, city, county, SIC (4-digit), name, address.

The information covers only employees under State disability compensation insurance, and files are maintained only for firms employing ten or more. A survey is also made of government and other non-covered employees by site.

The address shown is the tax address. Some firms operating from several locations may report through one address. Although some attempt is made to divide employees by site, the results may not be very accurate.

The SIC code given is for the primary activity of the firm only. In cases where firms engage in more than one activity the information is incomplete.

Construction employment is not available in the basic file. A survey of such employment is conducted but the data may be incomplete.

L.A. County Regional Planning Commission, the Southern California Association of Governments and the Department of Employment are investigating a new data system which will include all sites and all employees. This system is expected to be operational by 1970.

As an additional source of employment information, Dun & Bradstreet maintains a magnetic tape of information on manufacturing, transportation and utility firms. Name, address, SIC code (4-digit), number of employees and sales information are included on the tape. The L.A. County Regional Planning Commission has added Census tract number to its copy of the tape. This copy is available for L.A. County work, but for other activities it will be necessary to purchase the tape. The tape is updated yearly by Dun & Bradstreet. L.A. County has found some errors, but in general the tape is of high quality.

HOURS AND DAYS OPEN

No single agency collects these data although some data for retail businesses are included in License Applications in a few cities. The information is too variable to be easily collected; changes in season, contracts and so forth change the hours. At present, no plans are being made to gather these data.

NUMBER OF EMPLOYEES PRESENT BY HOUR

No single agency collects these data. Such data are not generally available, although some questionnaires have asked this question. As far as could be ascertained, there are no plans at present for gathering this information.

PERSONS OTHER THAN EMPLOYEES PRESENT BY HOUR

No single agency collects these data. Such data are not generally available though some questionnaires have asked this question. Aerial photos could be used to obtain estimates of numbers of cars in parking lots from which persons present could be inferred.

SIZE OF FACILITY

The L.A. County Assessor has information on facility floor areas, but the information is almost inaccessible because of Assessor office procedures. At present, the information is in manual paper files which the assessor has not made available; however, as the files are automated the information may become available.

VALUE OF SALES

Data on taxable sales are kept by the California State Board of Equalization; data on Industrial sales are available through Dun & Bradstreet. In both cases, the data are on magnetic tape and are updated regularly. The information is keyed to address.

Disclosure rules may affect the availability of Board of Equalization information, however, if the data are segregated and used by a public agency, they may be released.

NUMBER OF STUDENTS

Data on school enrollment are available through the L.A. County Superintendent of Schools' office. The data are on paper forms and are keyed to school and to school district. They are updated two times a year, October 1 and March 1. They cover elementary, Jr. High, High, Jr. College, and Adult Classes; also included are counts of faculty and staff. Private and parochial schools are not covered. The Catholic school information is available through the Catholic School Office of Los Angeles.

AVERAGE DAILY ATTENDANCE

Data are available through the L.A. County Superintendent of Schools office. The data are on paper forms and are maintained by school districts.

NUMBER OF PERSONS PRESENT IN HOSPITALS

The Hospital Planning Association of Southern California gathers information on hospitals for the SCAG (Southern California Association of Governments) Region. Hospital address is not coded to census tract. The data collected includes the number of licensed beds for each hospital and also information on specific occupancy on an annual basis, e.g., the number of patient days per hospital per year. At present, these items are updated annually, but the Association is attempting to develop a semi-annual update system. The information is in paper files.

The hospitals covered are the "Acute Care" hospitals. Convalescent hospitals and senior citizen homes are not included.

AERIAL PHOTOGRAPHY

A brief investigation of costs and current techniques using aerial photographs was conducted to see if this method is feasible for making estimates of the population in particular areas. Such estimates might be useful for special institutions such as beaches or recreational facilities and also for checking and comparison with other estimates. Counts could be made of people either directly, or indirectly through the count of automobiles.

To be able to make accurate counts of the numbers of people in streets, on the beach, or in any open area from aerial photographs, a fairly high degree of resolution is required. Photograph enlargements, one way of obtaining the resolution sufficient for such counts, entails several processing steps which may affect the final quality of the enlargements. Considerations of sharpness, resolving power, light quality and definition will influence the quality of the final enlarged prints.

Approximately 90 percent of the total cost for aerial photographs is in the enlargement process. One estimate received indicates that to enlarge a photograph taken from a 6,000 foot elevation of a rectangular area 2,250 in width and 4,500 in length to bring the scale to where personnel counts could be made with the unaided eye would cost approximately $550.

Because of the significant costs involved in enlargements, it would seem more practical both from a cost and resolution standpoint to utilize readily available optical scanners and other aids to increase image size rather than to rely on an extensive enlargement process of photographic negatives.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION FOR MODEL VALIDATION

It is a conclusion of this study that the model which is described above is a potentially useful tool for predicting population distribution by hour of the day and by S.L.A. In formulating the model, an effort was made, on the one hand, to restrict input requirements to generally available data, so that the model could be implemented in towns and cities throughout the nation with a minimum of supplementary data collection. And on the other hand, the model was designed so as to utilize all regularly collected relevant statistics, as well as results of related special surveys which may have been made in individual regions. The goal was to develop a model that is sufficiently flexible to include as inputs, wherever possible, supplementary local data on population distribution, as well as routinely collected population and employment statistics of the U.S. Census Bureau and the Bureau of Labor Statistics, school attendance records of school boards, and information derived from Origin and Destination Traffic Studies.

The next step in the development of the model is to test it. There is no other way to determine the accuracy with which the model describes the distribution of the population in S.L.A.'s on an hourly basis. As indicated in Chapter Two, there are, however, alternative methods for testing, which are dependent on the allowable budget and the product desired.

By far the cheapest of these validation methods is to use an Origin and Destination survey to estimate the spatio-temporal population distribution, and to compare the results with outputs of the model. In the selection of a region for making this type of comparison, factors to be considered are availability of Traffic Study data, and the feasibility of running the model for the same S.L.A.'s, year, and season as were employed in the Traffic Study. If a fairly recent Origin and Destination survey is used for testing the model, one may expect the collection of data for estimating variable inputs to be facilitated.

An initial test would involve the following steps:

- Data for the input variables of the model would be collected through survey of various agencies. These data would include for each S.L.A.: the number of non-institutional residents; the number of institutional residents; the number of employees of industry; the number of elementary and high school students enrolled; the number of special institutions which have to be considered separately; and the number of persons expected to be present in special institutions at designated times.

- From the Origin and Destination study and from school records, the following parameter inputs to the model would be generated for each hour: the proportion of residents at home; the ratio of persons present (employees and others) to the total number of employees in industry; the ratio of persons present (students and others) to the total number of students enrolled; and the proportion of persons enroute.

- Using the above variable and parameter inputs, the model would be implemented so as to obtain estimates of the numbers of persons present in each S.L.A. and for each hour of the day.

- The next step is to compare the model outputs with those obtained in some other manner. The comparison will be made with estimates that are derived from the same Origin and Destination survey data. For each time period, the population distribution among S.L.A.'s of the region will be estimated from trip records. As indicated in Chapter 4, person-presence records can be established for the respondents of the survey so as to facilitate the required computations.

The parameters are regional averages; in the model, they are assumed to be constant for the S.L.A.'s of the region. Deviations from these regional averages among the S.L.A.'s of the region will be reflected in differences between the model outputs and the direct estimates obtained from the survey sample.

This initial test is not designed to study regional and seasonal variations of parameters and variables. Initially, wherever possible, parameter and variable inputs of the model, on the one hand, and numbers of persons present in S.L.A.'s, on the other hand, are estimated for the same region, year, season, and days of the week. The sensitivity of model outputs to changes in regional or seasonal factors may be determined from comparisons under various combinations of these factors.

The next stage in testing is to investigate variations of parameters among regions, for the applicability of this methodology to regions throughout the nation will depend upon the magnitudes of these regional differences. This will require estimation of parameters from Origin and Destination survey data for different regions, and implementation of the model with alternative parameter values. The procedure is analogous to that described above for the initial test.

Finally, it may be noted that though this discussion assumes that the areal unit of interest is the S.L.A., this same model may be implemented for larger units, and the testing procedure described above applied to these units. In general, the larger the units the lower will be the costs of data collection. More aggregated models will be cheaper [illegible]. If int[illegible]est [illegible] fact on the S.L.A., [illegible] quick and easy method (Model 3) described in Chapter Three for deriving S.L.A. estimates from more aggregated ones can be experimented with and outputs tested as indicated above.

APPENDIX

TABLE A-1

RATIO OF NUMBER OF PERSONS PRESENT AT HOUR OF THE DAY TO NUMBER OF PERSONS PRESENT AT 4 P.M. DURING AN AVERAGE SUMMER WEEKDAY FOR RESIDENTIAL AREAS.

Time \ City	Erie	Flint	Grand Rapids	Minn. St. Paul	Phila. Camden
1 AM	1.354	1.274	1.384	1.356	1.265
2	1.364	1.303	1.386	1.365	1.270
3	1.366	1.329	1.388	1.368	1.272
4	1.368	1.339	1.389	1.368	1.272
5	1.455	1.340	1.386	1.368	1.271
6	1.450	1.307	1.374	1.359	1.263
7	1.361	1.204	1.256	1.303	1.219
8	1.223	1.156	1.154	1.118	1.114
9	1.186	1.127	1.098	1.071	1.060
10	1.139	1.092	1.065	1.047	1.045
11	1.104	1.041	1.033	1.020	1.023
12	1.082	1.022	1.023	1.004	1.095
1 PM	1.075	1.029	1.038	1.006	1.005
2	1.047	1.004	1.006	.992	.996
3	1.013	.992	.977	.989	.984
4	1.000	1.000	1.000	1.000	1.000
5	1.085	1.053	1.063	1.057	1.033
6	1.193	1.112	1.226	1.225	1.155
7	1.206	1.081	1.218	1.258	1.209
8	1.150	1.037	1.126	1.194	1.198
9	1.125	1.062	1.151	1.213	1.205
10	1.164	1.134	1.227	1.260	1.219
11	1.191	1.182	1.293	1.302	1.231
12	1.227	1.234	1.370	1.333	1.246

Source: Table 1, Appendix A, of University of North Carolina (1952).

TABLE A-2

RATIO OF NUMBER OF PERSONS PRESENT AT HOUR OF THE DAY TO NUMBER OF PERSONS PRESENT AT 4 P.M. DURING AN AVERAGE SUMMER WEEKDAY FOR COMMERCIAL AREAS.

Time \ City	Flint	Grand Rapids	Minn. St. Paul	Phila. Camden
1 AM	.200	.133	.222	.274
2	.186	.124	.209	.274
3	.186	.106	.209	.268
4	.186	.106	.209	.268
5	.171	.106	.196	.268
6	.171	.106	.203	.274
7	.200	.150	.229	.301
8	.286	.327	.464	.438
9	.514	.699	.804	.752
10	.757	.876	.941	.922
11	.928	1.035	1.020	1.007
12	.971	.991	1.046	1.052
1 PM	.971	..956	1.052	1.078
2	1.000	1.061	1.078	1.098
3	.985	1.106	1.078	1.085
4	1.000	1.000	1.000	1.000
5	.900	.752	.725	.804
6	.386	.239	.379	.431
7	.386	.204	.340	.392
8	.557	.380	.405	.418
9	.514	.389	.405	.418
10	.385	.310	.353	.366
11	.271	.221	.288	.333
12	.214	.141	.235	.288

Source: Table 1, Appendix A, of University of North Carolina (1952).

TABLE A-3

RATIO OF NUMBER OF PERSONS PRESENT AT HOUR OF THE DAY TO NUMBER OF PERSONS PRESENT AT 4 P.M. DURING AN AVERAGE SUMMER WEEKDAY FOR INDUSTRIAL AREAS.

Time \ City	Erie	Flint	Grand Rapids	Minn. St. Paul	Phila. Camden
1 AM	.614	.457	.438	.607	.354
2	.610	.279	.458	.607	.338
3	.610	.193	.451	.600	.338
4	.469	.136	.458	.593	.338
5	.469	.143	.471	.593	.354
6	.474	.300	.484	.607	.354
7	.570	.864	.765	.679	.462
8	.903	1.007	1.065	.879	.815
9	1.053	1.071	1.190	1.050	1.015
10	1.053	1.086	1.209	1.064	1.046
11	1.079	1.107	1.196	1.064	1.046
12	1.026	1.100	1.183	1.057	1.046
1 PM	1.000	1.079	1.111	1.057	1.031
2	1.000	1.150	1.163	1.057	1.031
3	1.044	1.278	1.176	1.057	1.046
4	1.000	1.000	1.000	1.000	1.000
5	.781	.829	.745	.757	.646
6	.618	.664	.608	.629	.431
7	.601	.664	.608	.621	.415
8	.583	.657	.536	.643	.415
9	.579	.679	.536	.657	.415
10	.579	.693	.523	.650	.400
11	.596	.729	.516	.629	.400
12	.588	.600	.510	.614	.369

Source: Table 1, Appendix A, of University of North Carolina (1952).

TABLE A-4

RATIO OF NUMBER OF PERSONS IN MOTION IN VEHICLES AT BEGINNING OF EACH HOUR PERIOD TO NUMBER OF PERSONS IN MOTION IN VEHICLES AT 4 P.M. DURING AN AVERAGE SUMMER WEEKDAY.

Time \ City	Flint	Grand Rapids	Minn. St. Paul	Phila. Camden
1 AM	.123	.086	.092	.086
2	.186	.043	.015	.057
3	.082	.057	.000	.029
4	.051	.029	.015	.029
5	.051	.029	.045	.057
6	.165	.157	.108	.171
7	.371	.814	.492	.171
8	.433	.886	1.400	1.800
9	.351	.443	.631	.971
10	.361	.343	.508	.400
11	.433	.357	.585	.429
12	.600	.457	.692	.457
1 PM	.600	.500	.662	.486
2	.619	.500	.708	.543
3	.753	.657	.769	.714
4	1.000	1.000	1.000	1.000
5	.804	1.329	1.661	2.057
6	.732	.971	.985	1.600
7	.763	.786	.631	.629
8	.856	1.042	.923	.686
9	.722	1.414	[illegible]	[illegible]
10	[illegible]	.686	.569	.457
11	.361	.500	.400	.486
12	.278	.129	.262	.430

Source: Table 1, Appendix A, of University of North Carolina (1952).

TABLE A-7

STATISTICAL TESTS OF DATA OF TABLE A-1

INDEPENDENT VARIABLE 1 IS TIME OF DAY
DEPENDENT VARIABLE 2 IS RESIDENTIAL AREA 2

SUMS FOR THE 23 GROUPS AND THE TOTAL

6.63300	6.68800	6.72300	6.73500	6. 2000	6.75300	6.34300	5.76500
5.54200	5.39300	5.22100	5.22600	5.15300	5.04500	4.95500	5.29100
5.91100	5.97200	5.70500	5.75500	6.00400	6.19900	6.41000	136.23900

SUMS OF SQUARES FOR THE 23 GROUPS AND THE TOTAL

8.81081	8.95543	9.04815	9.08307	9.32049	9.14067	8.06324	6.65470
6.15297	5.81224	5.45651	5.46878	5.31397	5.09234	4.91114	5.60034
6.99752	7.15377	6.52658	6.64166	7.21994	7.69802	8.23459	163.35395

BARTLETT HOMOGENEITY OF VARIANCES TEST, CHI-SQUARE = 21.67440, P = 0.47946 , WITH 22 DF

WELCH HOMOGENEITY OF MEANS TEST, F = 40.47771, P = 0.46859D-17, WITH DF1 = 22, AND DF2 = 33

ANOVA* TEST FOR HOMOGENEITY OF MEANS

SOURCE	DF	SUMS OF SQUARES	MEAN SQUARE	F	PROBABILITY	CORR. RATIO**
BETWEEN	22	1.7187	0.07812	30.61864	0.47665D-32	0.93799
WITHIN	92	0.23473	0.00255			
TOTAL	114	1.9534				

DEPENDENT VARIABLE
RESIDENTIAL AREA 2

GROUP			NUMBER	MEAN	STANDARD DEVIATION
1	1	A.M.	5	1.32660	0.05355
2	2	A.M.	5	1.33760	0.04888
3	3	A.M.	5	1.34460	0.04583
4	4	A.M.	5	1.34720	0.04565
5	5	A.M.	5	1.36400	0.06709
6	6	A.M.	5	1.35060	0.07084
7	7	A.M.	5	1.26860	0.06425
8	8	A.M.	5	1.15300	0.04375
9	9	A.M.	5	1.10840	0.05054
10	10	A.M.	5	1.07760	0.03916
11	11	A.M.	5	1.04420	0.03445
12	12	NOON	5	1.04520	0.04051
13	1	P.M.	5	1.03060	0.02868
14	2	P.M.	5	1.00900	0.02200
15	3	P.M.	5	0.99100	0.01355
16	5	P.M.	5	1.05820	0.01874
17	6	P.M.	5	1.18220	0.04882
18	7	P.M.	5	1.19440	0.06673
19	8	P.M.	5	1.14100	0.06554
20	9	P.M.	5	1.15120	0.06196
21	10	P.M.	5	1.20080	0.05084
22	11	P.M.	5	1.23980	0.05590
23	MID	NIGHT	5	1.28200	0.06513
TOTAL			115	1.18469	0.13090

*The ANOVA test is a one-way analysis of variance test.

**The CORR. RATIO is the square root of the ratio of the between to total sums of squares.

Notation: When a decimal contains the letter "D", the number following "D" is an exponent. The decimal is to be multiplied by 10 raised to this power. For example, .46859D-17 = (.46859)10^{-17}

TABLE A-6

STATISTICAL TESTS OF DATA OF TABLE A-2

INDEPENDENT VARIABLE 1 IS TIME OF DAY
DEPENDENT VARIABLE 4 IS COMMERCIAL AREAS 4

SUMS FOR THE 23 GROUPS AND THE TOTAL

0.82900	0.79300	0.76900	0.76300	0.74100	0.75400	0.88000	1.51500
2.76900	3.49600	3.99000	4.06000	4.05700	4.23700	4.25400	3.14100
1.43500	1.32200	1.76000	1.72600	1.41400	1.11300	0.87830	45.74200

SUMS OF SQUARES FOR THE 23 GROUPS AND THE TOTAL

0.18205	0.16873	0.16134	0.16134	0.15072	0.15676	0.20554	0.59586
1.96472	3.07599	3.98686	4.12574	4.12556	4.49341	4.53277	2.54754
0.53552	0.45989	0.79340	0.75427	0.50299	0.31611	0.20385	34.20044

BARTLETT HOMOGENEITY OF VARIANCES TEST, CHI-SQUARE = 10.60714, P = 0.97991 , WITH 22 DF

WELCH HOMOGENEITY OF MEANS TEST, F = 102.24.94, P = 0.230060-18, WITH DF1 = 22, AND DF2 = 25

ANOVA* TEST FOR HOMOGENEITY OF MEANS

SOURCE	DF	SUMS OF SQUARES	MEAN SQUARE	F	PROBABILITY	CORR. RATIO**
BETWEEN	22	10.127	0.46030	97.35583	0.233880-42	0.98427
WITHIN	69	0.32623	0.00473			
TOTAL	91	10.453				

DEPENDENT VARIABLE 4
COMMERCIAL AREAS 4

GROUP			NUMBER	MEAN	STANDARD DEVIATION
1	1	A.M.	4	0.20725	0.05842
2	2	A.M.	4	0.19825	0.06196
3	3	A.M.	4	0.19225	0.06707
4	4	A.M.	4	0.19225	0.06707
5	5	A.M.	4	0.18525	0.06695
6	6	A.M.	4	0.18850	0.06984
7	7	A.M.	4	0.22000	0.06309
8	8	A.M.	4	0.37875	0.08575
9	9	A.M.	4	0.69225	0.12633
10	10	A.M.	4	0.87400	0.08264
11	11	A.M.	4	0.99750	0.04772
12	12	NOON	4	1.01500	0.04017
13	1	P.M.	4	1.01425	0.05987
14	2	P.M.	4	1.05925	0.04230
15	3	P.M.	4	1.06350	0.05367
16	5	P.M.	4	0.79525	0.07715
17	6	P.M.	4	0.35875	0.08309
18	7	P.M.	4	0.33050	0.08747
19	8	P.M.	4	0.44000	0.07958
20	9	P.M.	4	0.43150	0.05626
21	10	P.M.	4	0.35350	0.03184
22	11	P.M.	4	0.27825	0.04627
23	MID	NIGHT	4	0.21950	0.06090
TOTAL			92	0.50807	0.33892

*The ANOVA test is a one-way analysis of variance test.

**The CORR. RATIO is the square root of the ratio of the between to total sums of squares.

Notation: When a decimal contains the letter "D", the number following "D" is an exponent. The decimal is to be multiplied by 10 raised to this power. For example, .23388D-42 = (.23388)10^-42.

TABLE A-7

STATISTICAL TESTS OF DATA OF TABLE A-3

RAW DATA FORMAT
(F2.0, F4.3)

INDEPENDENT VARIABLE 1 IS TIME OF DAY
DEPENDENT VARIABLE 1 IS INDUSTRIAL AREAS 1

SUMS FOR THE 23 GROUPS AND THE TOTAL

2.47000	2.29200	2.19700	1.99400	2.03000	2.21900	3.34000	4.55900
5.37900	5.45800	5.45200	5.41200	5.27800	5.40100	5.60100	3.75800
2.95000	2.90922	2.83400	2.86600	2.84500	2.87000	2.68100	82.90000

SUMS OF SQUARES FOR THE 23 GROUPS AND THE TOTAL

1.27145	1.14240	1.24633	0.91411	0.93922	1.04270	2.33111	4.40355
5.80467	5.97610	5.96150	5.87353	5.57877	5.85528	6.31756	7.84259
1.77389	1.72963	1.64451	1.58745	1.67152	1.70855	1.47900	63.03318

BARTLETT HOMOGENEITY OF VARIANCES TEST, CHI-SQUARE = 21.11353, P = 0.51373 , WITH 22 DF

WELCH HOMOGENEITY OF MEANS TEST, F = 30.82927, P = 0.30348D-15, WITH DF1 = 22, AND DF2 = 33

ANOVA* TEST FOR HOMOGENEITY OF MEANS

SOURCE	DF	SUMS OF SQUARES	MEAN SQUARE	F	PROBABILITY	CORR. RATIO**
BETWEEN	22	8.1066	0.36839	29.00447	0.39690D-31	0.93487
WITHIN	92	1.1685	0.01270			
TOTAL	114	9.2731				

DEPENDENT VARIABLE 1
INDUSTRIAL AREAS 1

GROUP			NUMBER	MEAN	STANDARD DEVIATION
1	1	A.M.	5	0.49400	0.11322
2	2	A.M.	5	0.45840	0.15145
3	3	A.M.	5	0.43840	0.17750
4	4	A.M.	5	0.39880	0.17241
5	5	A.M.	5	0.40600	0.16958
6	6	A.M.	5	0.44380	0.[illegible]2032
7	7	A.M.	5	0.66800	0.15810
8	8	A.M.	5	0.93380	0.10079
9	9	A.M.	5	1.07580	0.06698
10	10	A.M.	5	1.09160	0.06715
11	11	A.M.	5	1.090[illegible]0	0.064[illegible]9
12	12	NOON	5	1.08240	0.06241
13	1	P.M.	5	1.05560	0.042[illegible]6
14	2	P.M.	5	1.08020	0.07266
15	3	P.M.	5	1.12020	0.10407
16	5	P.M.	5	0.75160	0.06723
17	6	P.M.	5	0.59000	0.0[illegible]136
18	7	P.M.	5	0.58180	0.09640
19	8	P.M.	5	0.56680	0.09772
20	9	P.M.	5	0.57320	0.10567
21	10	P.M.	5	0.56900	0.11480
22	11	P.M.	5	0.57400	0.12367
23	MID	NIGHT	5	0.53620	0.10179
TOTAL			115	0.72087	0.28521

*The ANOVA test is a one-way analysis of variance test.

**The CORR. RATIO is the square root of the ratio of the between to total sums of squares.

Notation: When a decimal contains the letter "D", the number following "D" is an exponent. The decimal is to be multiplied by 10 raised to this power.

TABLE A-8

STATISTICAL TESTS OF DATA OF TABLE A-4

INDEPENDENT VARIABLE 1 IS TIME OF DAY
DEPENDENT VARIABLE 3 IS MOVING PERSONS 3

SUMS FOR THE 23 GROUPS AND THE TOTAL

0.38700	0.30100	0.16900	0.12400	0.18200	0.60100	1.84800	4.51900
2.39600	1.61200	1.80400	2.20600	2.24800	2.37000	2.89300	5.85100
4.28800	2.80900	3.53700	3.44800	2.27900	1.74700	1.09900	48.68800

SUMS OF SQUARES FOR THE 23 GROUPS AND THE TOTAL

0.03838	0.03992	0.01081	0.00451	0.00872	0.09278	1.07154	6.17248
1.66045	0.66603	0.84120	1.25656	1.28444	1.42927	2.09981	9.40283
5.00889	1.9937	3.14102	3.40689	1.32469	0.77652	0.34747	42.07901

BARTLETT HOMOGENEITY OF VARIANCES TEST, CHI-SQUARE = 108.71041, P = 0.187360-12, WITH 22 DF

WELCH HOMOGENEITY OF MEANS TEST, F = 54.13255, P = 0.685290-15, WITH DF1 = 22, AND DF2 = 25

ANOVA*TEST FOR HOMOGENEITY OF MEANS

SOURCE	DF	SUMS OF SQUARES	MEAN SQUARE	F	PROBABILITY	CORR. RATIO**
BETWEEN	22	12.776	0.58071	11.32855	0.330270-14	0.88497
WITHIN	69	3.5370	0.05126			
TOTAL	91	16.312				

DEPENDENT VARIABLE 3
MOVING PERSONS 3

GROUP			NUMBER	MEAN	STANDARD DEVIATION
1	1	A.M.	4	0.09675	0.01773
2	2	A.M.	4	0.07525	0.07587
3	3	A.M.	4	0.04225	0.03500
4	4	A.M.	4	0.03100	0.01488
5	5	A.M.	4	0.04550	0.01204
6	6	A.M.	4	0.15025	0.02874
7	7	A.M.	4	0.46200	0.26942
8	8	A.M.	4	1.12975	0.59642
9	9	A.M.	4	0.59900	0.27401
10	10	A.M.	4	0.40300	0.07393
11	11	A.M.	4	0.45100	0.09592
12	12	NOON	4	0.55150	0.11540
13	1	P.M.	4	0.56200	0.08379
14	2	P.M.	4	0.59250	0.09138
15	3	P.M.	4	0.72325	0.04984
16	5	P.M.	4	1.46275	0.53050
17	6	P.M.	4	1.07200	0.37065
18	7	P.M.	4	0.70225	0.08396
19	8	P.M.	4	0.87675	0.14862
20	9	P.M.	4	0.96200	0.38066
21	10	P.M.	4	0.56975	0.09351
22	11	P.M.	4	0.43675	0.06712
23	MID	NIGHT	4	0.27475	0.12318
TOTAL			92	0.52922	0.42339

*The ANOVA test is a one-way analysis of variance test.

**The CORR. RATIO is the square root of the ratio of the between to total sums of squares.

Notation: When a decimal contains the letter "D", the number following "D" is an exponent. The decimal is to be multiplied by 10 raised to this exponent.

TABLE A-9

MEANS AND STANDARD DEVIATIONS OF RATIOS OF NUMBERS OF PERSONS PRESENT (EMPLOYEES AND OTHERS) AT 2:30 P.M. TO TOTAL EMPLOYMENT FOR FOUR CITIES* ON AN AVERAGE WEEKDAY IN JANUARY 1956.

INDUSTRY AND LOCATION	EMPLOYEES PRESENT		OTHERS PRESENT	
	Mean	Standard Deviation	Mean	Standard Deviation
Retail Trade				
Downtown Tracts	.85	.05	.54	.09
Other Tracts	.71	.09	.76	.32
Finance, Insurance, Real Estate				
Downtown Tracts	.83	.06	.13	.05
Other Tracts	.70	.06	.25	.18
Manufacturing				
Downtown Tracts	.89	.09	-	-
Other Tracts	.77	.04	-	-
All Others				
Downtown Tracts	.77	.05	.28	.05
Other Tracts	.71	.11	.31	.14

* The cities are Houston, Milwaukee, St. Louis and W hington, except in the case of Manufacturing, Downtown Tracts, for which Washington is omitted.

Source: Computations are based on data in Bureau of the Census (1956), Table C, page 41.

FIGURE A-1

URBANIZED AREAS IN WHICH ORIGIN AND DESTINATION TRAFFIC STUDIES HAVE BEEN MADE.

STATE	URBANIZED AREA
Alabama	Birmingham, Gadsden, Huntsville, Mobile, Montgomery, Tuscaloosa
Arizona	Phoenix, Tucson,
Arkansas	Fort Smith, Little Rock-North Little Rock, Pine Bluff
California	Bakersfield, Fresno, Los Angeles-Long Beach, Oxnard, Pomona-Ontario, Sacramento, Salinas-Monterey, San Bernardino-Riverside, San Diego, San Francisco-Oakland, San Jose, Santa Barbara Stockton,
Colorado	Colorado Springs, Denver, Pueblo
Connecticut	Bridgeport, Hartford, Meriden, New Britain, New Haven, Norwalk, Stamford, Waterbury
Delaware	Wilmington
District of Columbia	District of Columbia
Florida	Ft. Lauderdale-Hollywood, Jacksonville, Miami, Orlando, Pensacola, St. Petersburg, Tallahassee, Tampa, West Palm Beach
Georgia	Albany, Atlanta, Augusta, Columbus, Macon, Savannah
Hawaii	Honolulu
Idaho	Boise
Illinois	Aurora, Bloomington-Normal, Champaign-Urbana, Chicago-N.W. Indiana (Cook, DuPage Kane, Lake, McHenry, and Will counties, Illinois portion), Chicago-N.W. Indiana

STATE	URBANIZED AREA
Illinois (Cont'd)	(Lake County, Illinois Portion), Davenport-Rock Island-Moline, Decatur, Joliet, Peoria, Rockford, Springfield
Indiana	Anderson, Chicago-N.W. Indiana (Lake and Porter Counties, Indiana portion), Evansville, Fort Wayne, Indianapolis, Lafayette-West Lafayette, Muncie, South Bend, Terre Haute
Iowa	Cedar Rapids, Davenport-Rock Island-Moline, Des Moines, Dubuque, Omaha-Countil Bluffs, Sioux City, Waterloo
Kansas	Topeka, Wichita
Kentucky	Lexington, Louisville
Louisiana	Baton Rouge, Lafayette, Lake Charles, Monroe, New Orleans, Shreveport
Maine	Lewiston-Auburn, Portland
Maryland	Baltimore
Massachusetts	Boston, Brockton, Fall River, Fitchburg-Leominster, Lawrence-Haverhill, Lowell, New Bedford, Pittsfield, Springfield-Chicopee-Holyoke, Worcester
Michigan	Ann Arbor, Bay City, Detroit, Flint, Grand Rapids, Jackson, Kalamazoo, Lansing, Muskegon-Muskegon Heights, Saginaw
Minnesota	Duluth-Superior, Minneapolis-St. Paul
Mississippi	Jackson
Missouri	Kansas City, St. Joseph, St. Louis, Springfield
Montana	Billings, Great Falls
Nebraska	Lincoln, Omaha-Council Bluffs
Nevada	Las Vegas, Reno

STATE	URBANIZED AREA
New Hampshire	Manchester
New Jersey	Atlantic City, Trenton
New Mexico	Albuquerque
New York	Albany-Schenectady-Troy, Binghamton, Buffalo, New York, Rochester, Syracuse, Utica-Rome
North Carolina	Asheville, Charlotte, Durham, Fayetteville, Greensboro, High Point, Raleigh, Wilmington, Winston-Salem
North Dakota	Fargo-Moorhead
Ohio	Akron, Canton, Cincinnati, Cleveland, Columbus, Dayton, Hamilton, Lima, Lorain-Elyria, Mansfield, Springfield, Steubenville-Weirton, Toledo, Youngstown-Warren
Oklahoma	Lawton, Oklahoma City, Tulsa
Oregon	Eugene, Portland, Salem
Pennsylvania	Allentown-Bethlehem, Altoona, Erie, Harrisburg, Johnstown, Lancaster, Philadelphia, Pittsburgh, Reading, Scranton, Wilkes-Barre, York
Puerto Rico	Mayaguez, Ponce, San Juan
Rhode Island	Providence-Pawtucket
South Carolina	Charleston, Columbia, Greenville
South Dakota	Dioux Falls
Tennessee	Chattanooga, Knoxville, Memphis, Nashville
Texas	Abilene, Amarillo, Austin, Beaumont, Corpus Christi, Dallas, El Paso, Fort Worth, Galveston Texas City, Harlingen-San Benito, Houston, Laredo, Lubbock, Midland, Odessa, Port Arthur, San Angelo, San Antonio, Texarkana, Tyler, Waco, Wichita Falls

STATE	URBANIZED AREA
Utah	Ogden, Provo-Orem, Salt Lake City
Virginia	Lynchburg, Newport News-Hampton, Norfolk-Portsmouth, Richmond, Roanoke
Washington	Seattle, Spokane, Tacoma
West Virginia	Charleston, Huntington-Ashland, Wheeling
Wisconsin	Duluth-Superior, Green Bay, Kenosha, Madison, Milwaukee, Racine

CONTACTS WITH TRAFFIC STUDY PERSONNEL

Communication was established with the following administrators of Traffic Studies:

LARTS and San Diego

Mr. Charles G. Beer, Urban Planner

Mr. James Frank, Urban Planner

Mr. J. A. Legarra, State Highway Engineer

Mr. Norman P. Roy, Statistical Analyst

BATSC

Mr. Jay McBride, Technical Director

CATS

Mr. John J. Howe, Supervisor, Data Services Division

TRISTATE

Mr. William Harting, Chief of Data Services

Mr. Max Schwartz, Chief of the Data Processing Division

CONTACTS WITH THE BUREAU OF LABOR STATISTICS

The following individuals discussed with SDC the feasibility of adding an additional questionnaire to the BLS Payroll Survey:

Mr. Robert O. Dorman
Chief, Industry and Employment, Statistics Division

Mr. Harold Goldstein
Assistant Commissioner for Manpower and Employment

SPAN AND MIDAS: LARGE-SCALE DATA MANAGEMENT AND ANALYSIS[1]

The SPAN system implemented at the Bay Area Transportation Study Commission was developed specifically to deal with certain aspects of transportation study data management. SPAN includes standard file manipulation and data reduction capabilities, matrix operations, statistical processes, plotter display capabilities and report generation. SPAN was originally designed to support the Penn-Jersey Transportation Study, and was completed in support of the Bay Area Transportation Study. The system operates on the IBM 7094 computer and includes a library of generalized programs for file processing, statistical analysis and graphic display. These programs operate on data supplied to them and the specific elements of each operation are defined by parameters. The parameters are provided through an English-text job control language which includes the ability to specify data transformation algorithms and data stratification rules. A SPAN application consists of a sequence of job steps, each invoking a particular processing capability in an arbitrary order determined by the user. The data structures upon which SPAN operates are self-defining so that the required information about data format and coding is automatically communicated from module to module of the system.

A feature which has greatly reduced the costs of assimilating into the SPAN system bodies of data required to support various statistical studies is the self-describing MIDAS (MIxed DAta Structure) file which permits the automatic processing of a large population of already existing BCD files. The processing subsystem designed to handle these files was developed specifically to handle origin and destination, land use inventory, and other survey-type data for the Bay Area Transportation Study. The MIDAS Processor permits the user to accept inputs whose records are not uniform, and from them construct files arrayed hierarchically according to an organizing scheme expressed at execution time. From an existing Home Interview File or from raw inputs, MIDAS can produce a multi-level organized file based on the necessary criteria, such

1. Taken from TM-3920/000/01, "An Information System to Urban Transportation Planning: The BATSC Approach," 15 May 1968, pp. 17 & 18.

as mode of transportation within travel purpose within zone of destination within zone of origin. The data can be selected to exclude automatically those entries not germane for the particular analysis, such as trips not involving automobiles. The same set of inputs may be used, with different organization and selection keys for different purposes. MIDAS accepts a simple parameter language which controls the selection and organization of data, the transformation of data according to arithmetic or logical rules, the amalgamation of data, and the summarization of data. It includes a flexible report generation capability. Thus complex files of varying structure, which in normal data processing shop experience have been quite difficult to process, can be reduced by relatively simple operations.

SPAN makes it possible to perform a variety of computations on data, from simple tabulation (such as totaling the number of cars) to the less common data analysis operations of factor and regression analysis and matrix processing. Information may be organized by arbitrary geographic boundaries through a grid coordinate selector (point-in-polygon) technique, and results of operations may be recorded in a variety of forms including computer printout and graphic plots. The output from any SPAN operation may be used as input to a subsequent SPAN operation without intermediate action; in fact, a sequence of unrelated operations can be linked together in a single computer run.

ABBREVIATIONS

BATSC - Bay Area Transportation (San Francisco) Study

CATS - Chicago Area Transportation Study

ID - Identification

LARTS - Los Angeles Regional Transportation Study

LU - Land Use

MIDAS - System for processing files, which was especially developed for the Bay Area Transportation Study.

SLA - Standard Location Area

SPAN - Library of generalized programs for the manipulation and statistical analysis of large bodies of data.

TRI-STATE - New York Area Transportation Study

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13. ABSTRACT

This document describes the results of an investigation of the feasibility of developing a method for determining the spatio-temporal distribution of the population. A model is described which can be used to determine the location of the population in Standard Location Areas on an hourly basis. Costs for acquisition of the data inputs to the model and processing of the model are estimated, and a method for validating the model is suggested.

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